Optical Gravitational Lensing Experiment. Photometry of the MACHO-SMC-1 Microlensing Candidate. *

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ABSTRACT

We present photometric observations of the MACHO-SMC-1 microlensing candidate collected by the OGLE-2 project. We show light curves of both components of the 1.6 arcsec blend: microlensed star and its optical companion. We find the contribution of the optical companion to the total flux to be 24% and confirm presence of the small amplitude periodic oscillations in the light curve of the lensed star with the period of 5.096 days and amplitude 0.05 mag. The lensed star is probably an ellipsoidal binary system.

1. Introduction

Discovery of the first microlensing event candidate toward the Small Magellanic Cloud by the MACHO Collaboration (Alcock *et al.* 1997) opens a new direction in which probing of the Galactic halo with microlensing phenomena can be possible. Although it may take years before a significant sample of events in this direction will be collected allowing to draw sound conclusions about distribution of mass in the Galactic halo, the first candidate itself seems to be very interesting.

*Based on observations obtained with the 1.3 m Warsaw telescope at the Las Campanas Observatory of the Carnegie Institution of Washington.

The microlensed source is a relatively bright ($V \sim 17.7$ mag) main sequence star blended with a fainter object. Contribution of the companion was estimated to be 23–28% of the total blend light. The event duration was 242 days (Einstein diameter crossing time) and the magnification reached maximum of 2.4 on January 11, 1997 (Alcock *et al.* 1997; parameters derived taking into account blending). Symmetric light curve and good achromaticity make this brightening an excellent microlensing event candidate. However, it should be noted that the position of the lensed star on the color-magnitude diagram is dangerously close to the non-periodic variable stars which can mimic microlensing.

The MACHO-SMC-1 candidate was also observed by the EROS group (Palanque-Delabrouille *et al.* 1997). They covered mostly the rising branch of the event. They found that the lensed star exhibits small, periodic variations of light with the amplitude of a few percent and the period of 5.123 days. However, due to poor resolution they were only able to perform photometry of the entire blend and could not assign those possible variations to any of the blended components.

Parameters of the event, in particular its long duration, suggest that the lensing object could be a massive body ($\sim 2.5 M_\odot$) in the Galactic halo or alternatively an object in the SMC (Alcock *et al.* 1997).

The SMC is one of the targets of the second phase of the Optical Gravitational Lensing Experiment – OGLE-2 (Udalski, Kubiak and Szymański 1997). Although observations of the majority of fields in the SMC started in June 1997, well after the event reached maximum of light, we decided to analyze OGLE-2 data of the MACHO-SMC-1 event to clear up the questions concerning possible variability of the lensed star and contribution of the blend components to the total flux. In this paper we present our results.

2. Observations

The OGLE-2 project observations are carried out at the Las Campanas Observatory, Chile, which is operated by the Carnegie Institution of Washington, with the 1.3-m Warsaw telescope equipped with the "first generation" CCD camera. Details of the equipment and data reduction techniques can be found in Udalski, Kubiak and Szymański (1997).

Observations of the SMC are made in the driftscan mode with drifts in declination. One scan covers approximately 14×56 arcmins on the sky. Majority of scans are obtained with the I-band filter, with some measurements in V and B-bands. The effective exposure time is 120 sec, 180 sec

and 240 sec for I, V, and B-bands, respectively. Observations of the field in which the MACHO-SMC-1 candidate was identified – SMC_SC8 – started on Jun. 27, 1997. The data presented in this paper cover the period through Oct. 9, 1997 (JD 2450730.6).

3. Results

Fig. 1 shows a 30×30 arcsec subframe centered on the MACHO-SMC-1 candidate taken at 1.0 arcsec seeing conditions. As can be seen the blend is easily resolved and both components could be easily measured independently with the OGLE-2 software. The I-band light curves of both stars are presented in Figs. 2 and 3. The zero point was chosen as the normal (off-event) brightness of the lensed star, calculated by fitting to our observations the theoretical microlensing light curve with Alcock *et al.* (1997) parameters. Error bars correspond to the errors returned by the photometry program (DoPhot) rescaled by a factor of 1.3 to approximate the observational errors. Errors of both components, in particular the fainter component of the blend, are larger than for typical stars of such brightness due to relatively small separation. The distance between components is 1.6 arcsec.

As can be seen from Figs. 2 and 3, the magnified star was the brighter component of the blend. Although the observations begun more than 5 months after the maximum of brightness, the star was still slightly above its normal brightness and the slow fading can still be noticed. The fainter component of the blend was constant over the entire period of observations. The normal state brightness of the lensed star and the mean magnitude of the fainter companion suggest that, in the I-band, the brighter component contributes 76% to the total light. Both components of the blend have almost exactly the same $V - I$ colors. Thus, in the V-band contribution of the fainter component is very similar. Both stars are located among the SMC main sequence stars on the color magnitude diagram.

To check for periodic variability reported by Palanque-Delabrouille *et al.* (1997) we performed a period analysis of the light curves of both components with the CLEAN algorithm (Roberts, Lehár and Dreher 1987). For the brighter star we first rectified the light curve by subtracting microlensing brightening. The analysis yields the periodicity of 5.096 days for the brighter star. No significant period was found for the fainter star. We also checked photometry of two nearby stars of similar brightness and again no significant periodicity was found.

Fig. 4 shows rectified observations of the brighter star folded with the

period of 5.096 day. Clear sinusoidal variations can be noticed. We fit a sinusoid to the data. The full amplitude (peak to peak) of the best fit is about 0.05 mag. Elements of minimum of brightness are given by the following equation:

$$\begin{aligned} \mathrm{JDhel.} = \quad & 2450625.612 + 5.096 \times P \\ \pm \quad & 0.050 \pm 0.025\,. \end{aligned}$$

4. Conclusions

Analysis of the photometric data of the MACHO-SMC-1 microlensing event candidate collected in the course of the OGLE-2 program indicates that the star which underwent magnification was the brighter component of the blend separated by 1.6 arcsec. Light curve of the fainter component shows no significant light variations. The brighter star contributes 76% to the blend light in the V and I-bands.

The light curve of the microlensing candidate shows additional small amplitude periodic variations with the period of 5.096 days – close to the value reported by the EROS group. Also the amplitude of sinusoidal variations is similar. As our data cover mostly the off-microlensing light curve while the EROS data were taken during the event, this may suggest that the amplitude is constant and is not related to microlensing. Most likely the star is a binary system with one or both components ellipsoidally distorted. Changing aspects cause small amplitude, sinusoidal variations similar to those observed in the light curve of the lensed star. The real period of the binary system would be twice of that derived in Section 3, that is 10.19 days. As the star is relatively bright, this hypothesis can be relatively easy verified by spectroscopic observations.

Photometry of the MACHO-SMC-1 candidate can be retrieved from the OGLE network archive: *ftp://sirius.astrouw.edu.pl/ogle/ogle2/macho-smc-1.*

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REFERENCES

Alcock, C., *et al.* 1997, preprint astro-ph/9708190.
Palanque-Delabrouille, N., *et al.* 1997, preprint astro-ph/9710194.
Roberts, D.H., Lehár, J., and Dreher, J.W., 1978, *Astron. J.*, **93**, 968.
Udalski, A., Kubiak, M., and Szymański, M. 1997, *Acta Astron.*, **47**, 319.

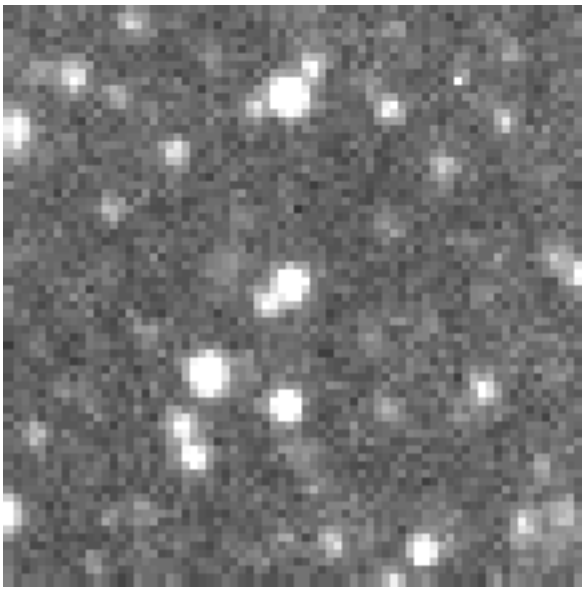
Figure Captions

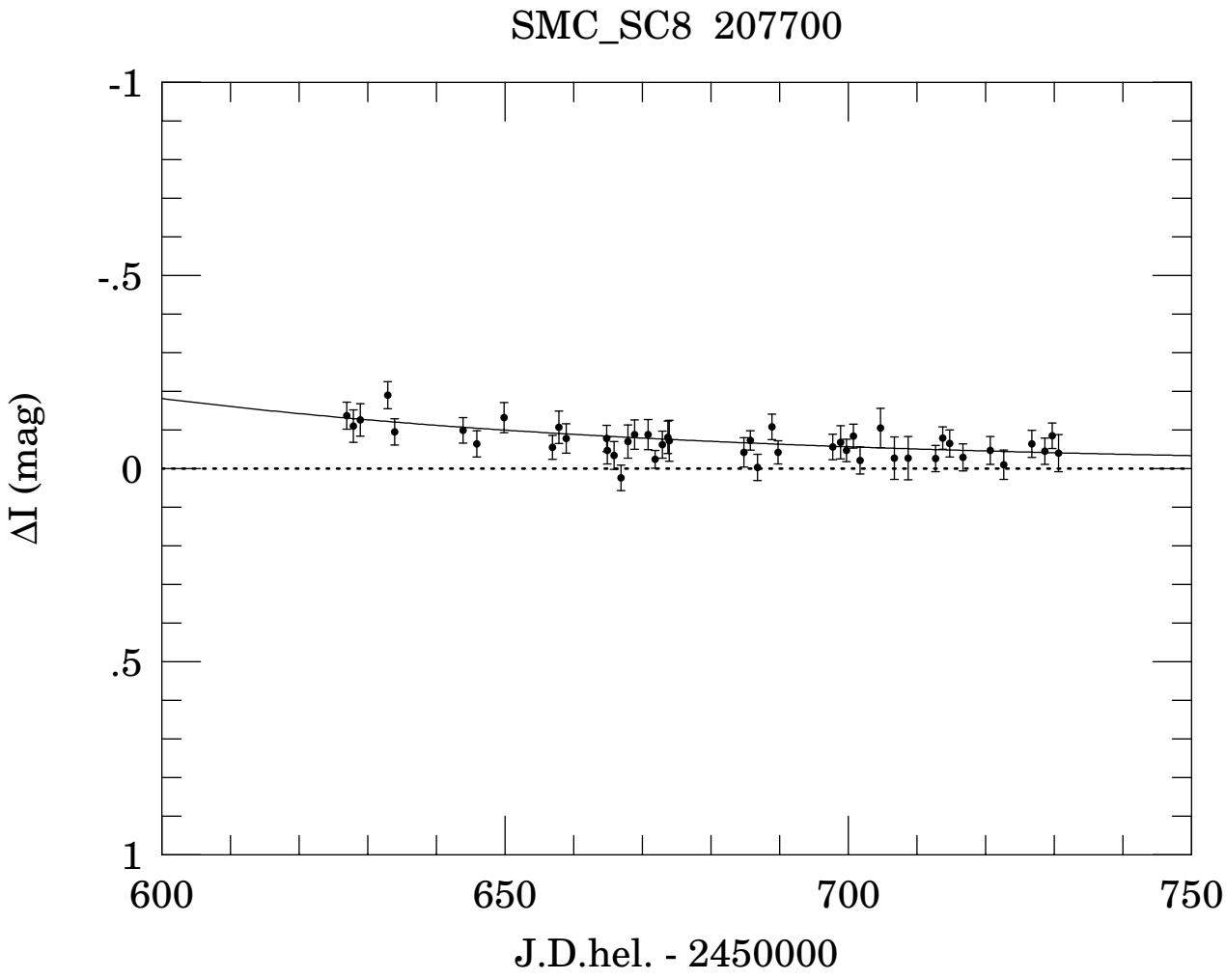
Fig. 1. 30×30 arcsec subframe centered on the MACHO-SMC-1 microlensing event candidate. North is up and East to the left.

Fig. 2. The I-band light curve of the microlensed star. Solid line shows the theoretical microlensing light curve of MACHO-SMC-1. Broken line indicates the normal brightness of the star.

Fig. 3. The I-band light curve of the star separated by 1.6 arcsec from the microlensed star. Broken line indicates its mean magnitude.

Fig. 4. Observations of the microlensed star phased with the period of 5.096 days. Thick, solid line indicates the best fit sinusoid. Two cycles are repeated for clarity.

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.5
1
ΔI (mag)
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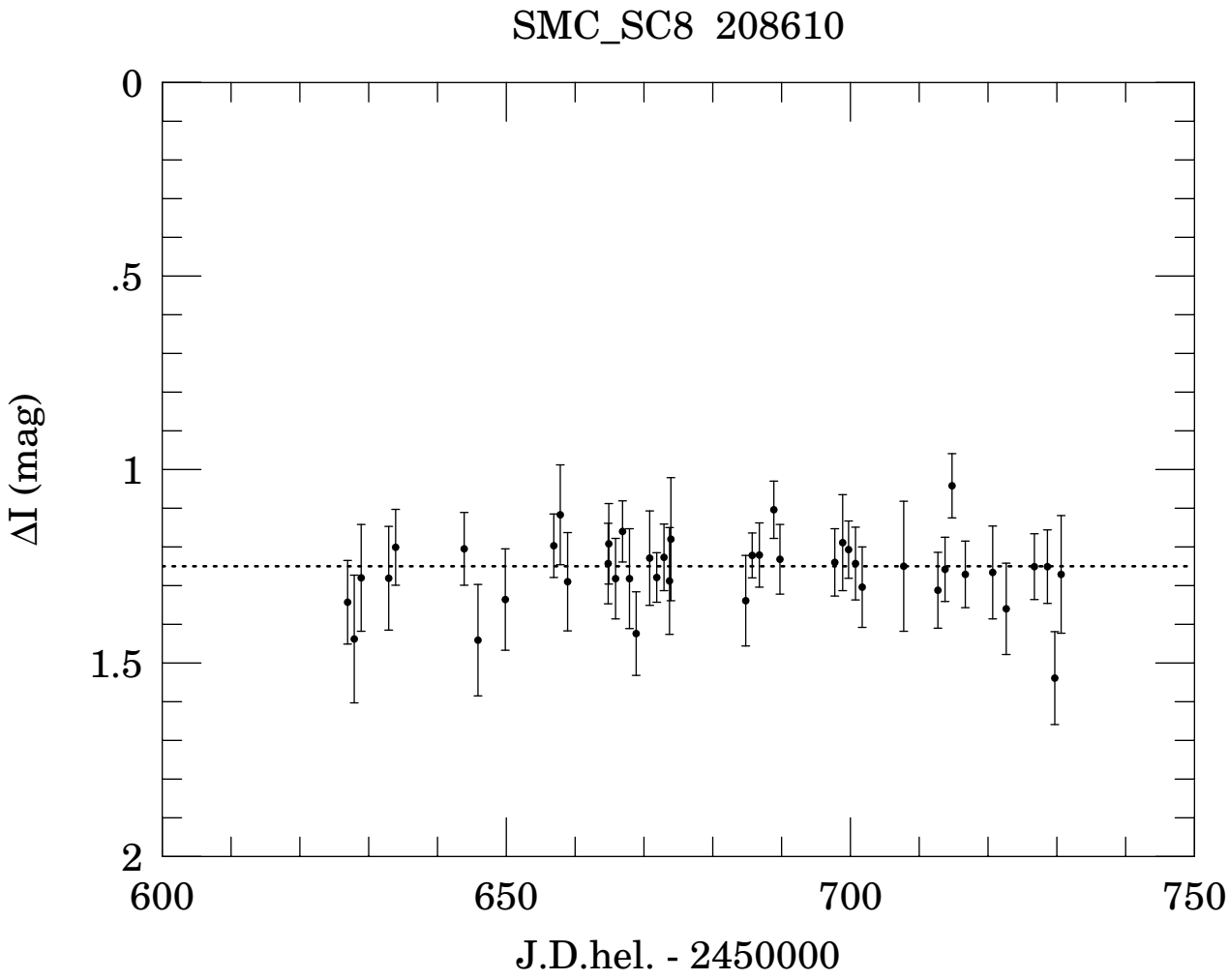
650
700
750
J.D.hel. - 2450000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2
ΔI (mag)
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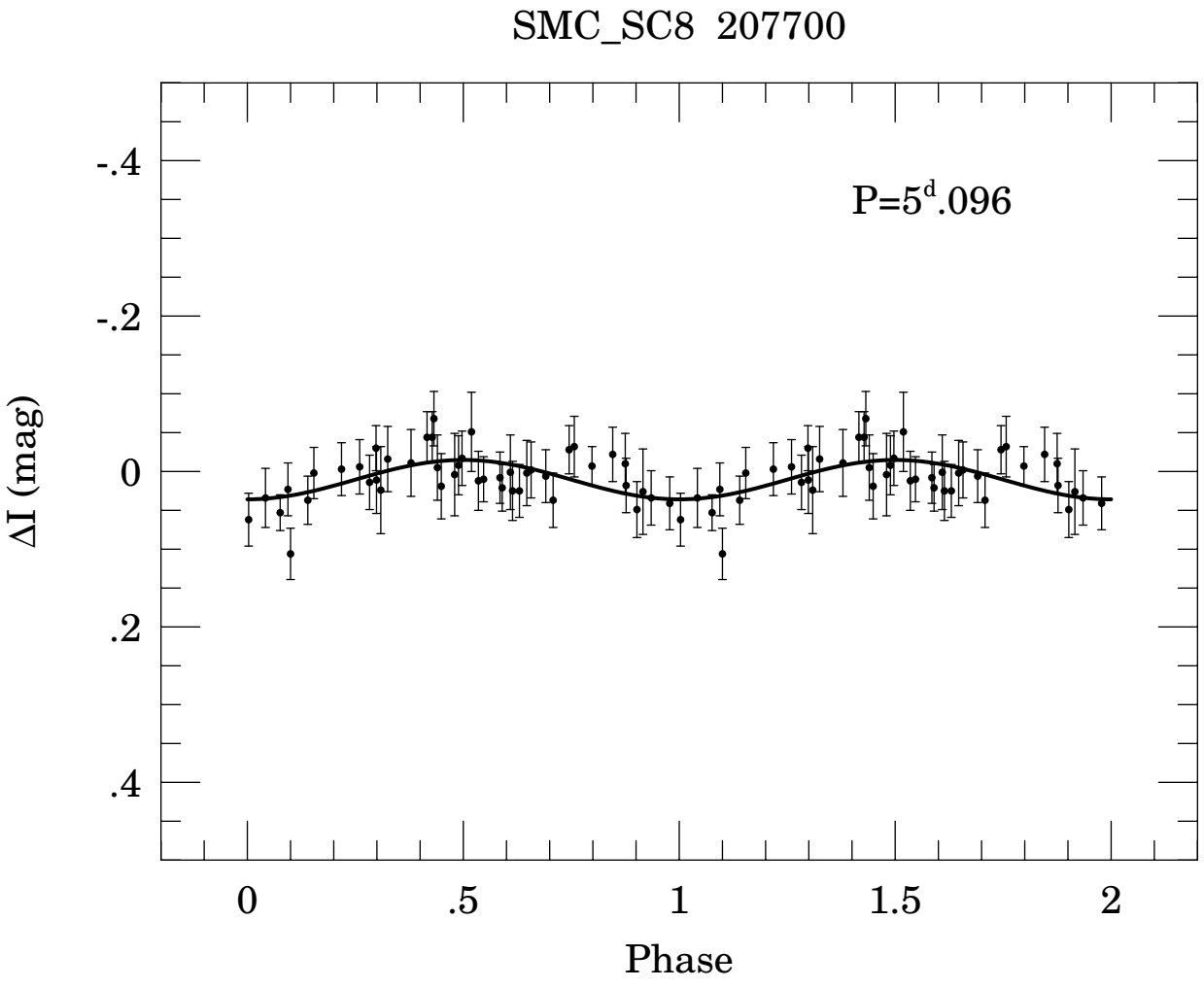
700
750
J.D.hel. - 2450000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0
.5
1
1.5
2
Phase